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LONG-PERIOD SUMMATION PROCESSING

Special Scientific Report No. 20

LARGE-ARRAY SIGNAL AND NOISE ANALYSIS

Prepared by

Leo N. Heiting

Frank H. Binder, Program Manager

1-214-238-3473

TEXAS INSTRUMENTS INCORPORATED

Science Services Division

P.O. Box 5621

Dallas, Texas 75222

Contract No. AF 33(657)-16678

Prepared for

AIR FORCE TECHNICAL APPLICATIONS CENTER

Washington, D.C. 20333

Sponsored by

ADVANCED RESEARCH PROJECTS AGENCY

ARPA Order No. 599

AFTAC Project No. VT/6707

20 September 1968

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INTRODUCTION

Ten LASA long-period event records were demultiplexed and displayed for use in a signal extraction study. The displays of these records provide interesting information regarding the character of events as seen by the various long-period sensors. This report presents these displays and relevant event information. In addition, time-shift-and-sum outputs of the vertical, horizontal inline, and horizontal transverse elements have been formed for several of the events. Appropriate Rayleigh wave velocities were used for the vertical and inline sums, while the transverse elements were beamed with Love wave velocity.

Examination of the traces and beamsteer outputs leads to the following conclusions:

- A given event is perceived with considerable dissimilarity by the various LASA sensors. At a given location, however, the Rayleigh-wave vertical and horizontal components have similar waveforms and are about equal in amplitude. The ratio of Love- to Rayleigh-wave peak amplitude varies from about 0.5 to 2.0

- Despite the waveform dissimilarity, beams formed with elements from the A0 through the D-ring show less than 1-db signal attenuation for Rayleigh waves. Rayleigh wave beams using the entire array show 1- to 3-db signal attenuation

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SECTION II
DATA DISPLAY

Plots of the ten events are given in Figures II-1 through II-24. Figure II-25 shows the beamsteers for the A0, C and D rings. Pertinent event information obtained from Preliminary Determination of Epicenter (PDE) data for these events appears in Table II-1. The data have been sampled with a 1-sec sampling period. The time scale in all plots is 200 sec/division. The same amplitude scale is used in all plots; i.e., one division represents the same amplitude in all cases. However, the traces have been multiplied by the scale factors given in Table II-2 (and shown on the figures) before plotting because of the wide range of amplitudes.

For events where horizontal components are displayed, the N-S and E-W components have been trigonometrically rotated to form components inline with and transverse to the great circle path from the epicenter to LASA. Three time-shift-and-sum outputs are given for four of the events. (Elements used in forming the beams were the nine sensors in the A0, C-, and D-rings [ACD], the nine sensors in the A0, E-, and F-rings [AEF], and all nonanomalous sensors [ALL].) Great circle azimuths were used for these beams. Velocity used for the vertical and inline horizontal components was 3.5 km/sec; that for the transverse horizontal components was 3.9 km/sec. These are the estimated fundamental mode Rayleigh- and Love-waves phase velocities at 0.05 Hz for LASA, respectively.

Waveforms of the Rayleigh- and Love-wave arrivals for the various events are seen to be strikingly different. More importantly, the waveforms for individual events vary considerably across the array. Multipath propagation and local scattering resulting in complex interference patterns are possible reasons for this second observation. Conclusive proof of this, however, seems difficult.

Table II-1

EVENT DATA

Region	Date	Origin Time (GMT)	Latitude (°)	Longitude (°)	Depth (km)	Magnitude	Δ (°)	Azimuth (°)
New Hebrides Islands	11/23/66	02:19:13.8	14.9S	166.9E	48	5.6	98.6	257.5
Hokkaido, Japan	11/12/66	12:49:43.6	41.8N	144.1E	33R	5.8	72.7	312.5
Mongolia	1/20/67	01:57:23.1	48.0N	102.9E	33	6.1	82.3	340.7
El Salvador	12/27/66	21:22:14.8	13.2N	88.8W	66R	5.5	36.5	150.6
New Guinea	12/14/66	21:07:52.1	4.8S	143.9E	74	6.0	107.1	281.4
Virgin Islands	4/06/67	03:07:05.5	19.6N	64.2W	13	4.6	43.6	118.0
Sea of Okhotsk	11/22/66	06:29:53.5	48.2N	146.7E	453R	5.6	66.1	315.6
Solomon Islands	1/13/67	13:48:11.7	10.6S	161.4E	32	5.7	99.3	260.0
California	11/11/66	18:21:05.0	40.3N	127.1W	33R	4.5	16.4	254.6
Greenland Sea	11/18/66	18:48:43.9	73.4N	6.8E	33R	4.9	51.9	19.7

Table II-2

MULTIPLICATIVE SCALE FACTORS

Event	Scale Factor for Vertical Seismometers	Scale Factor for Horizontal Seismometers
New Hebrides	5	5
Hokkaido	5	5
Mongolia	2	1
El Salvador	5	5
New Guinea	5	4
Virgin Islands	20	20
Sea of Okhotsk	5	5
Solomon Islands	5	
California	20	
Greenland Sea	20	

Comparing various beamsteer outputs with the corresponding A0 seismometer traces gives a rough estimate of signal attenuation ranges as shown in Table II-3.

Table II-3

AMOUNT OF SIGNAL ATTENUATION

Sensors	Vertical (db)	Inline Horizontal (db)	Inline Transverse (db)
ACD	0-1	0-1	1.5-2
ALL	1-2	1.5-3	1.5-4
AEF	1.5-5.5	2.5-6	3-6

Beamsteers using elements close to the A0 sensor provide surprisingly good replicas of long-period events as seen by the A0 sensor. In particular, for Rayleigh waves, beams formed with sensors out through the D-ring result in almost no signal attenuation. The four events used in reaching this conclusion range in PDE magnitude from 5.5 to 6.1 and in epicentral distance from 36.5° to 98.6°.

Although the vertical sensor traces for a given event are fairly dissimilar, there is good similarity between the vertical and inline horizontal traces at a single sensor location. Moreover, the ratio of the peak amplitude on the A0 vertical to that on the A0 horizontal inline ranges from 0.8 to 1.2. It appears that the Rayleigh wave vertical- and horizontal-component amplitudes for these events are roughly equal. A similar comparison of the vertical and horizontal transverse components results in a range of 0.5 to 2.0. The relative amounts of Rayleigh- and Love-wave power in these events covers a fairly wide range. The Mongolia event, which is the richest in relative Love-wave power, also has a large number of distinct phase arrivals. The level of activity on the vertical sensors, prior to the onset of the Rayleigh wave for this event, is noteworthy. Measurement of the moveout for this energy and its sharp reduction by the AEF vertical beamsteer supports the thesis that this is not Rayleigh-wave energy. The C4 vertical trace, seen inverted in this display, was corrected before the beamsteers were formed.

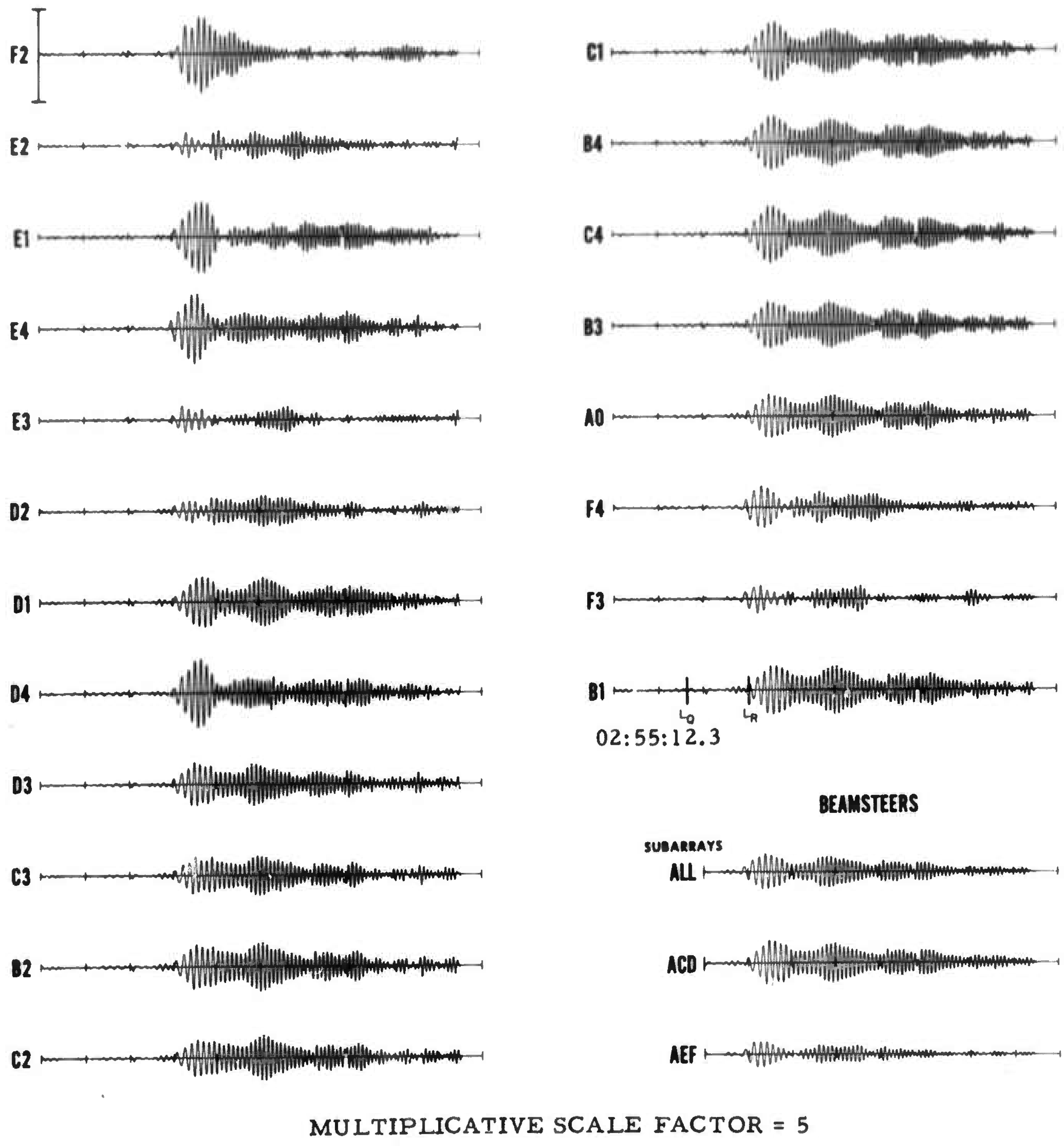
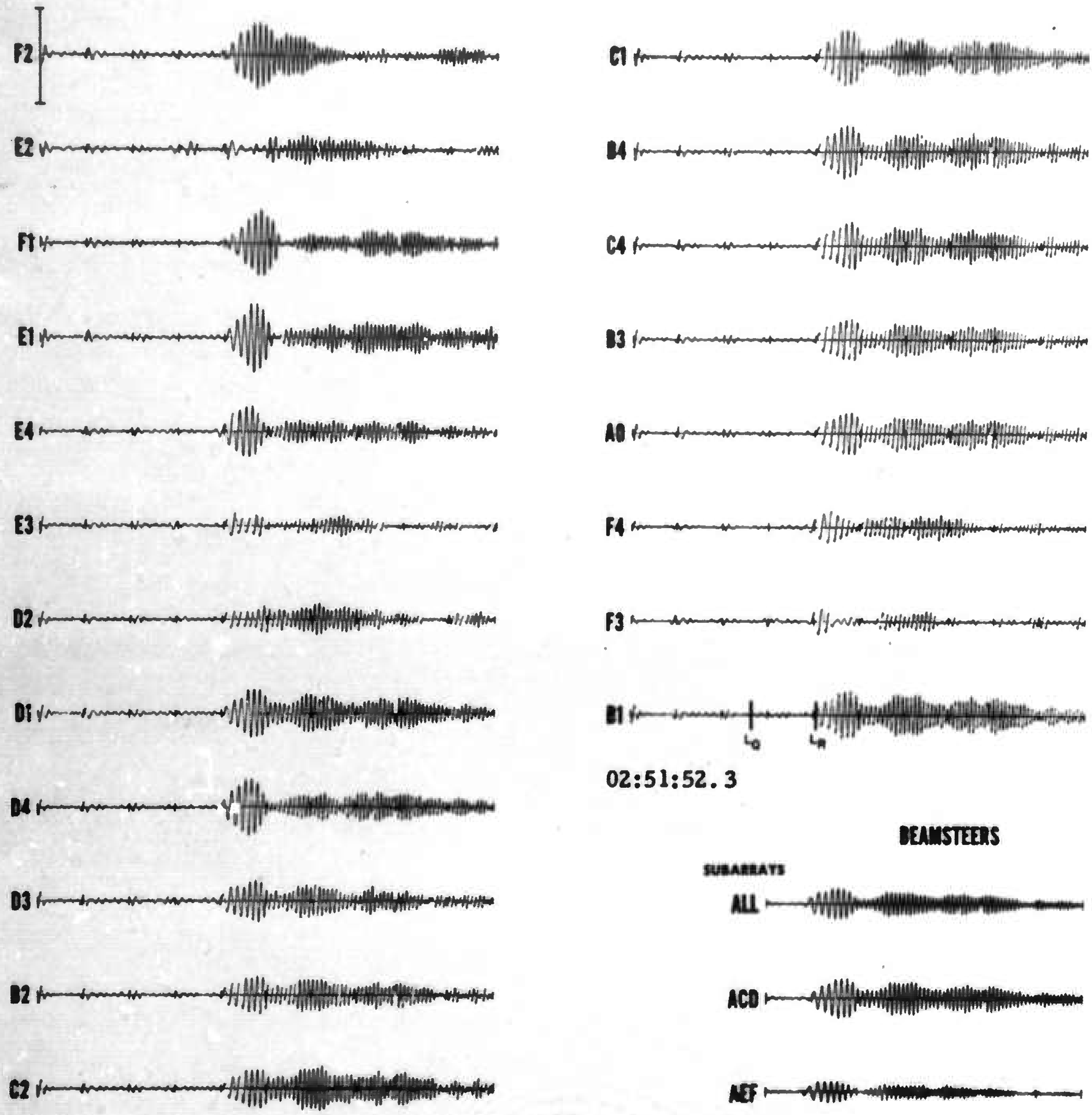


Figure II-1. New Hebrides Islands Vertical



MULTIPLICATIVE SCALE FACTOR = 5

Figure II-2. New Hebrides Islands Inline

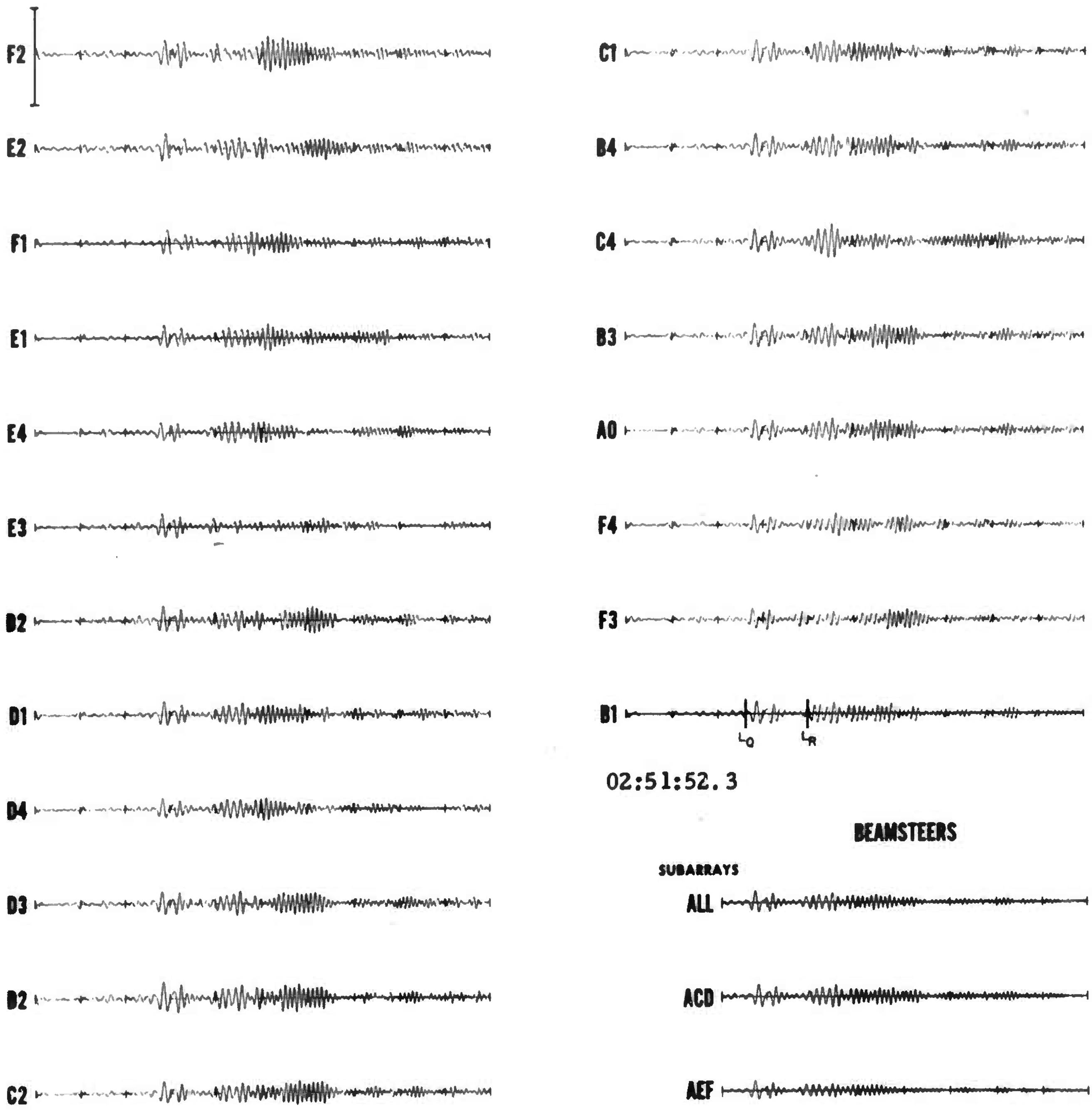


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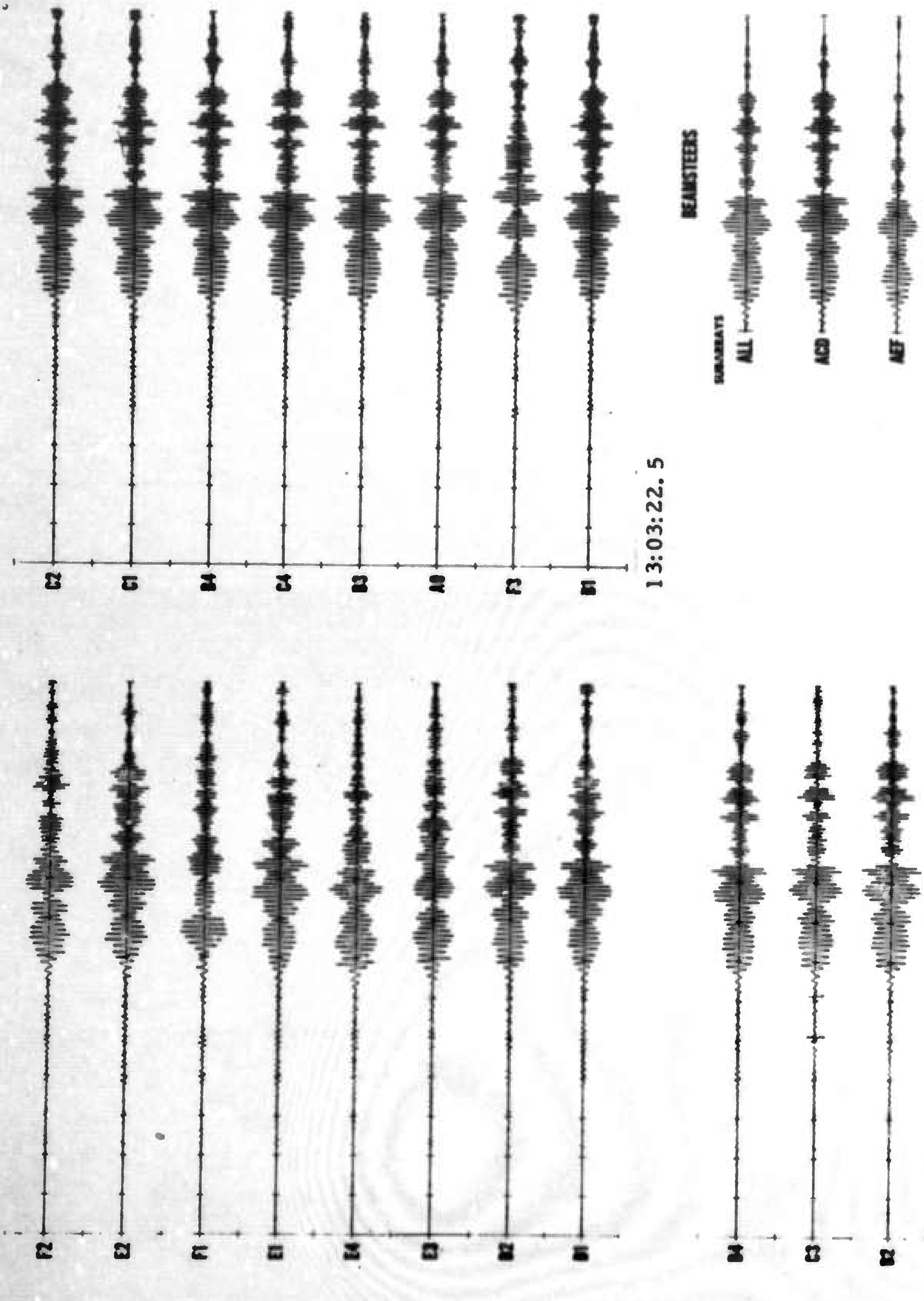
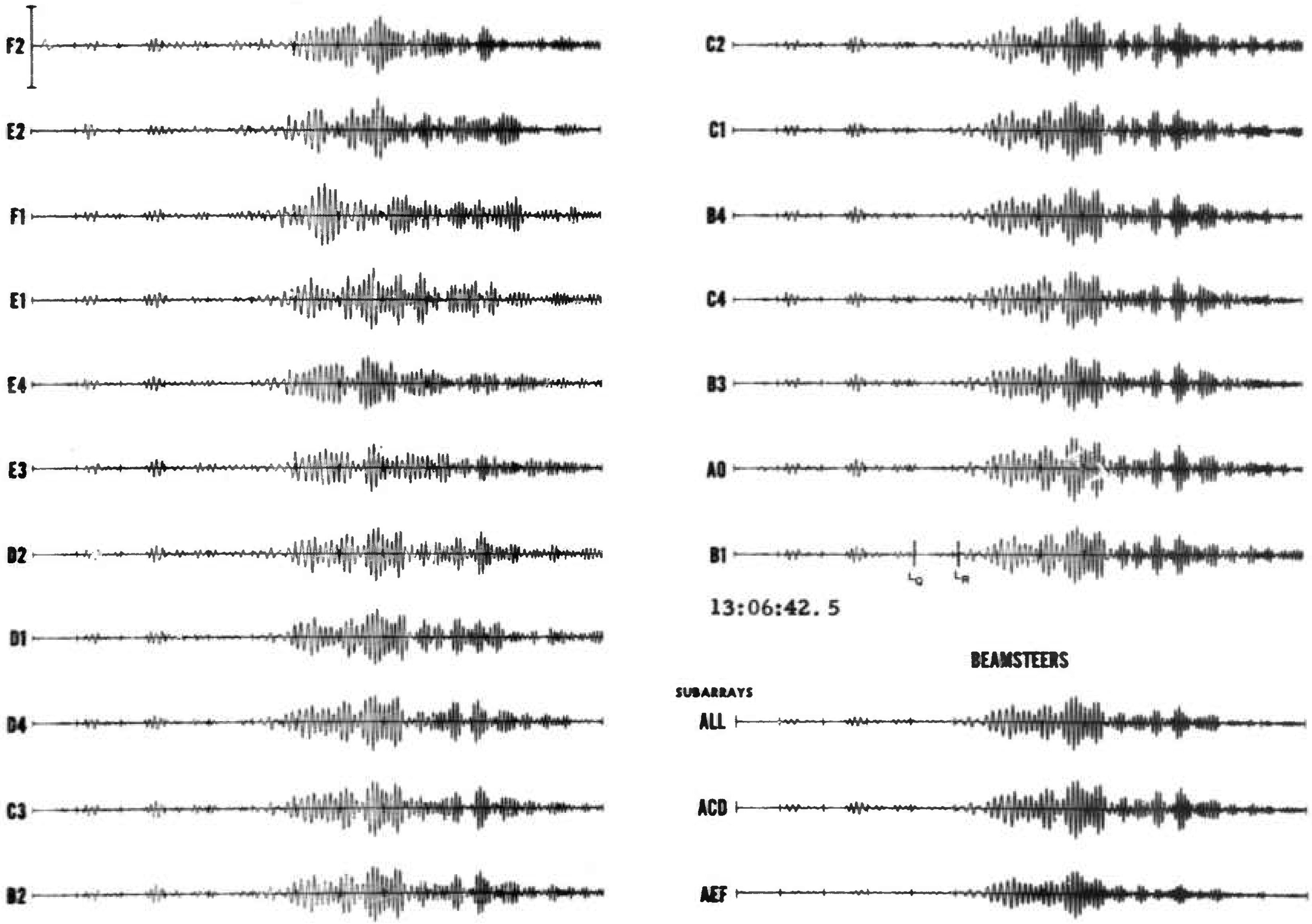
Figure II-3. New Hebrides Islands Transverse



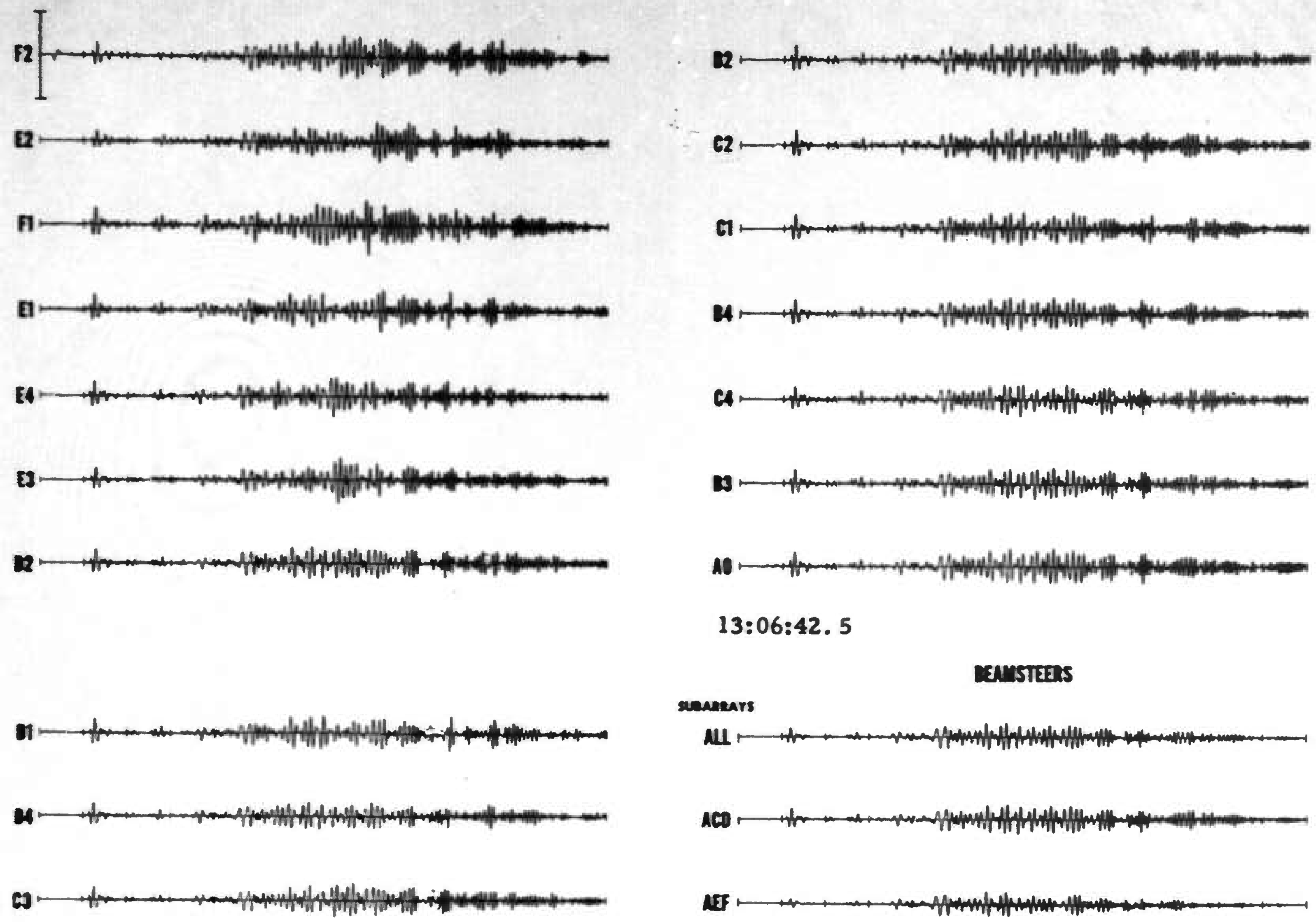
MULTIPLICATIVE SCALE FACTOR = 5

Figure II-4. Hokkaido Vertical



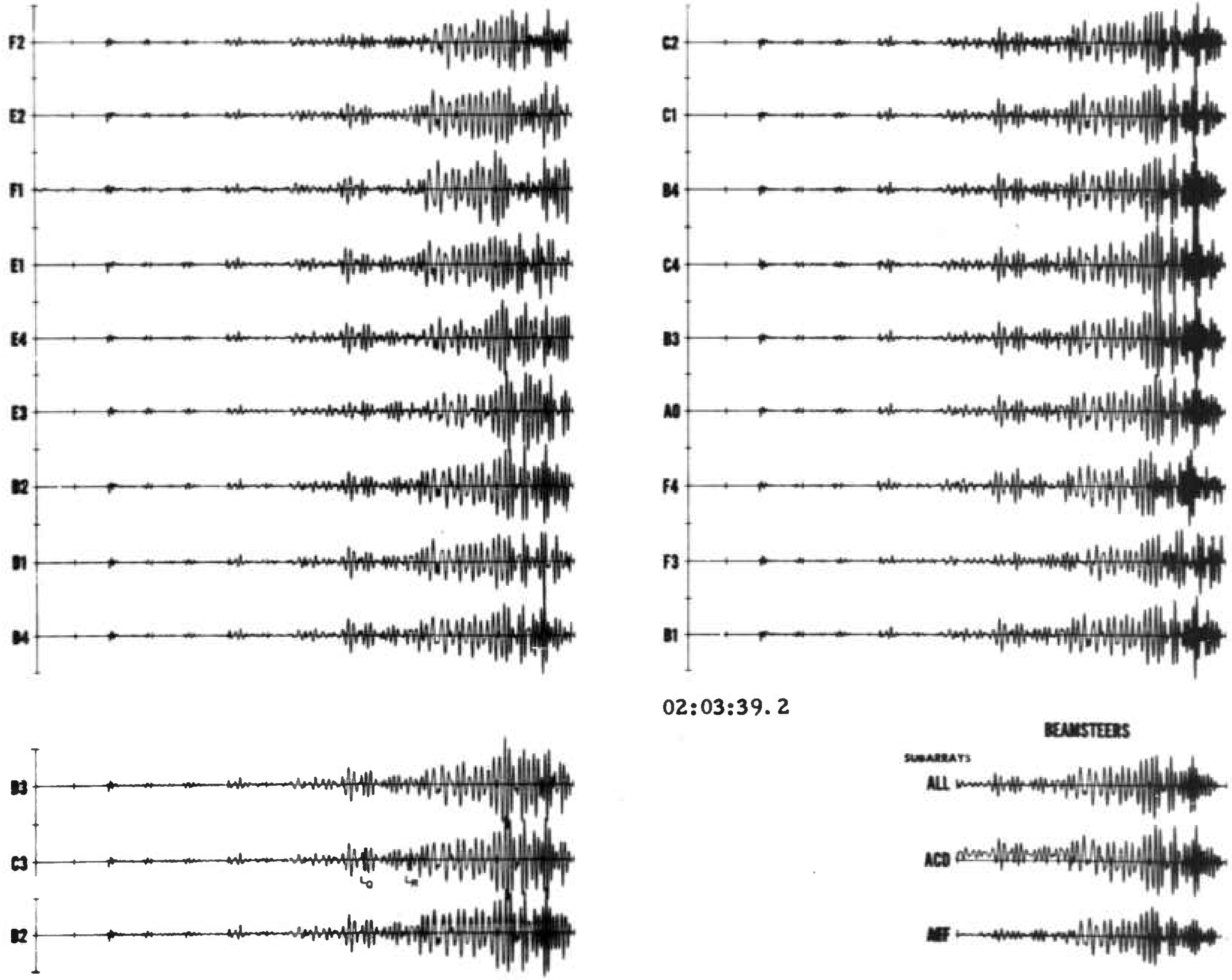
MULTIPLICATIVE SCALE FACTOR = 5

Figure II-5. Hokkaido Inline



MULTIPLICATIVE SCALE FACTOR = 5

Figure II-6. Hokkaido Transverse



MULTIPLICATIVE SCALE FACTOR = 2

Figure II-7. Mongolia Vertical

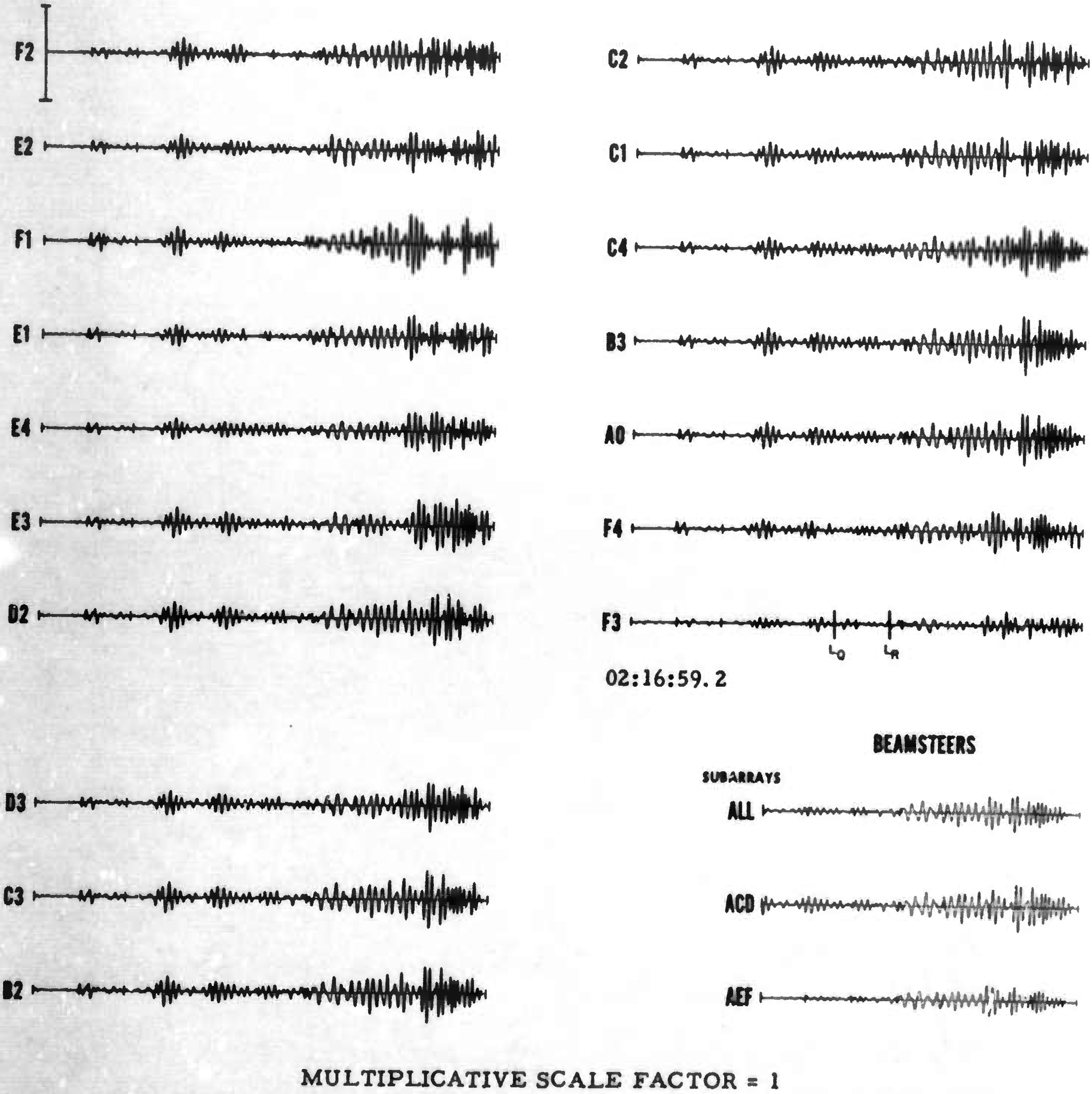


Figure II-8. Mongolia Inline

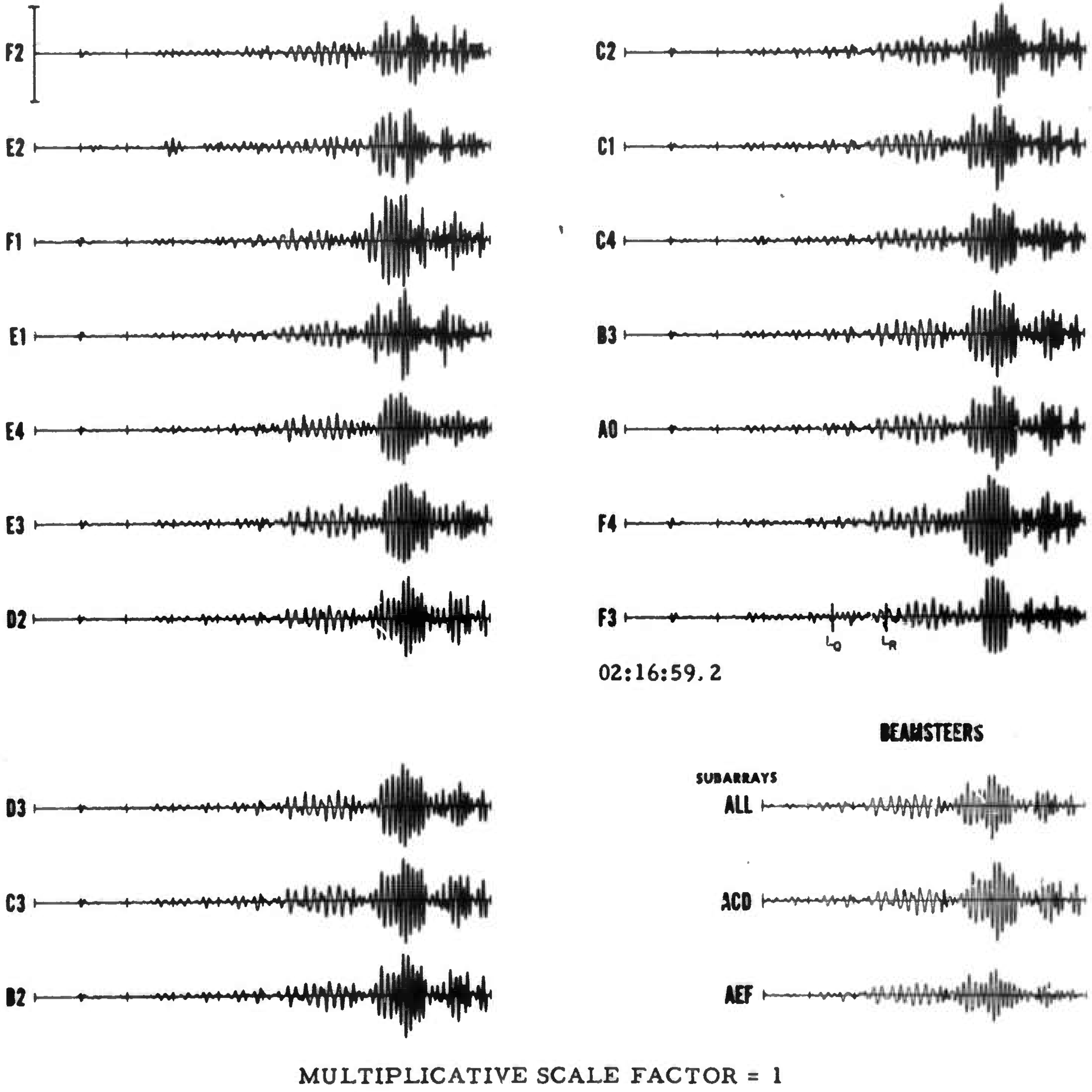
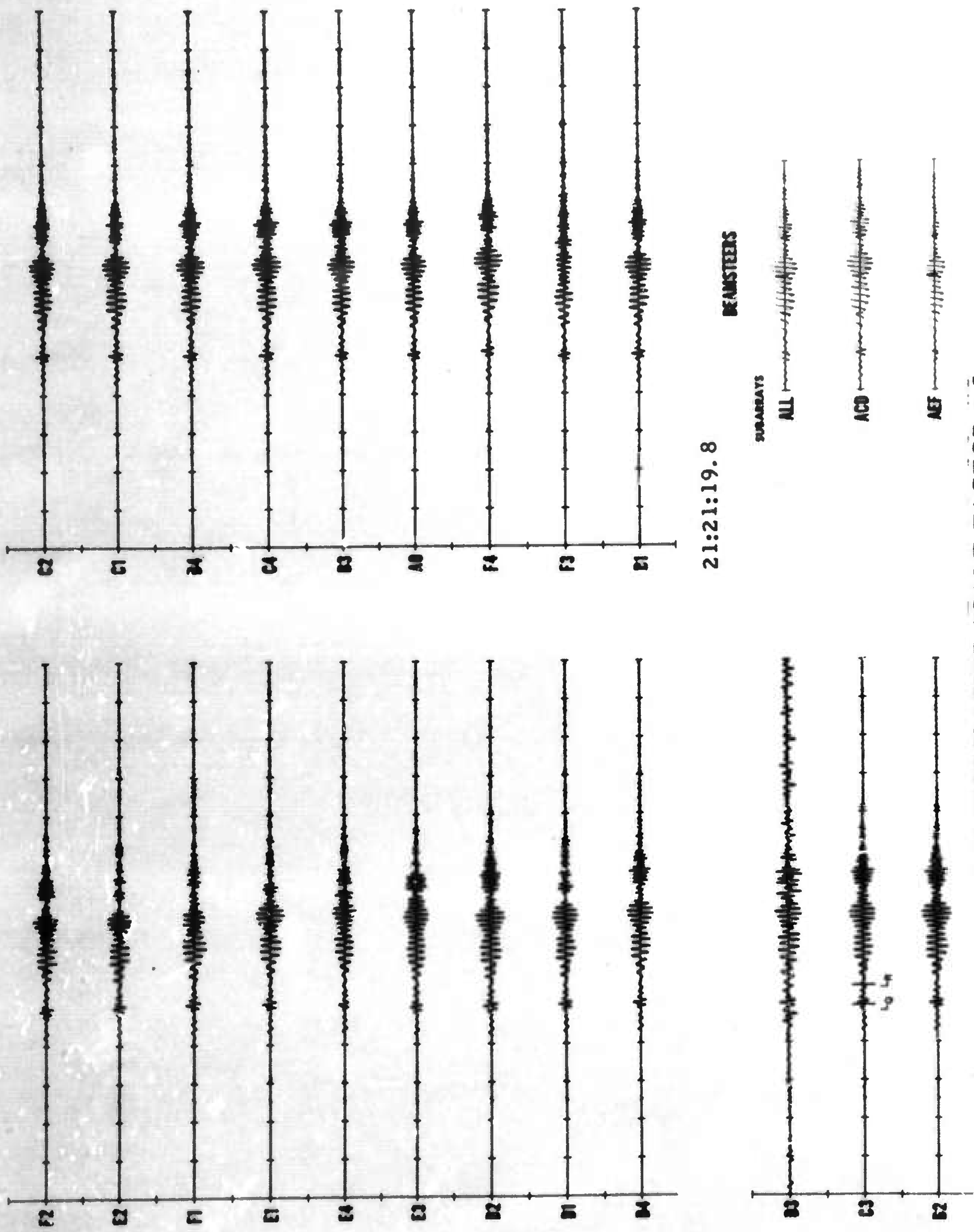
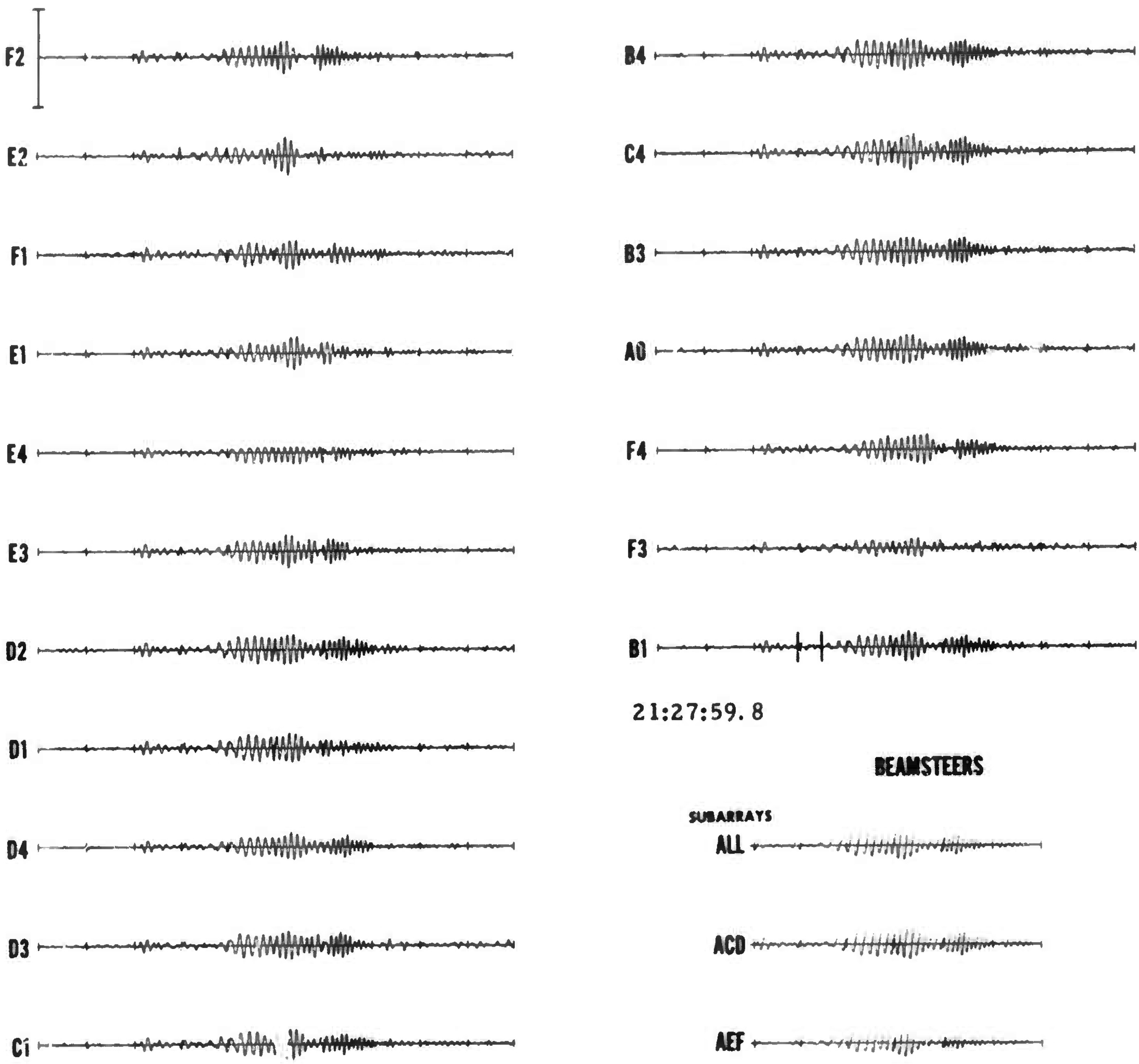


Figure II-9. Mongolia Transverse



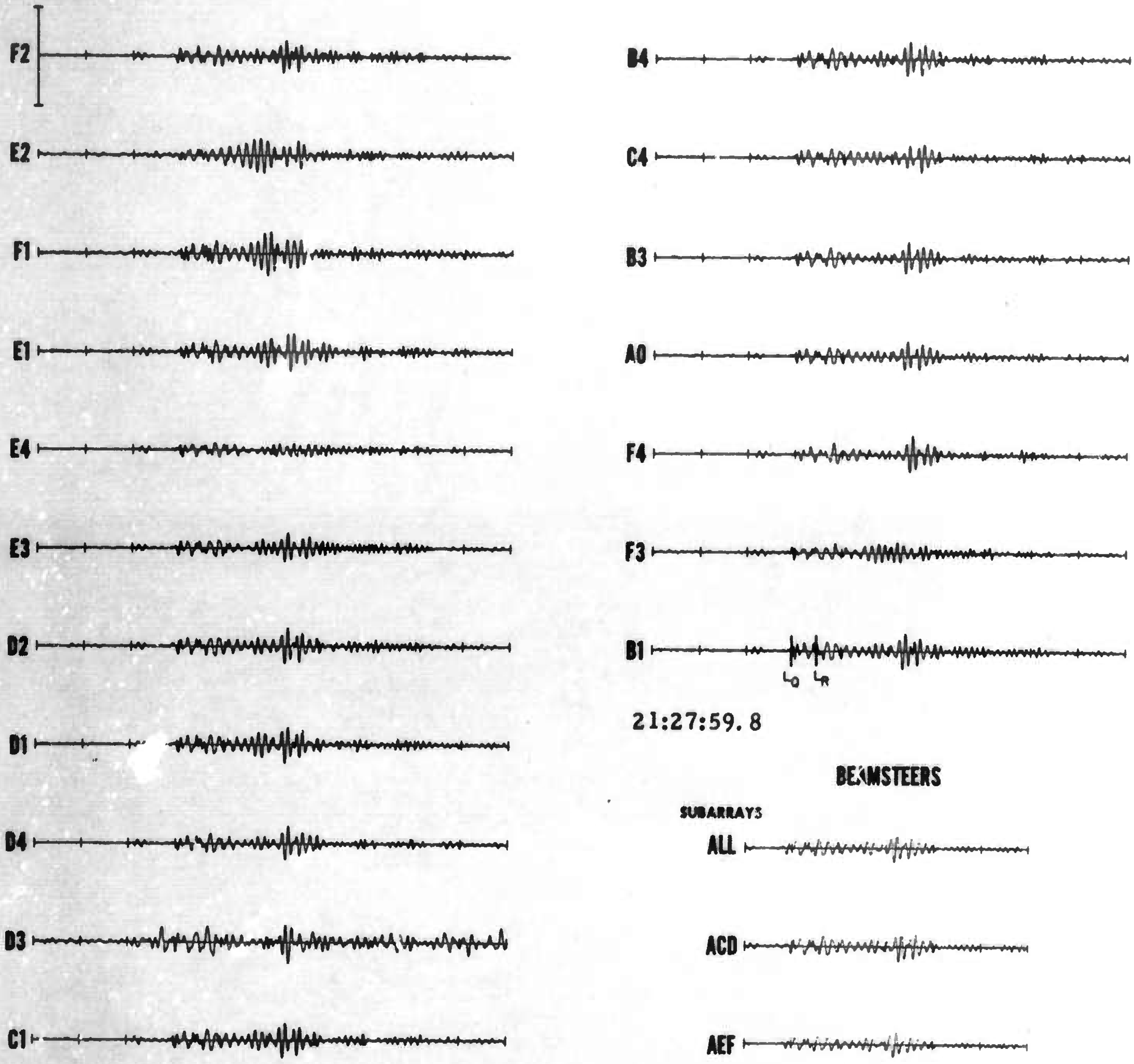
MULTIPLICATIVE SCALE FACTOR = 5

Figure II-10. El Salvador Vertical



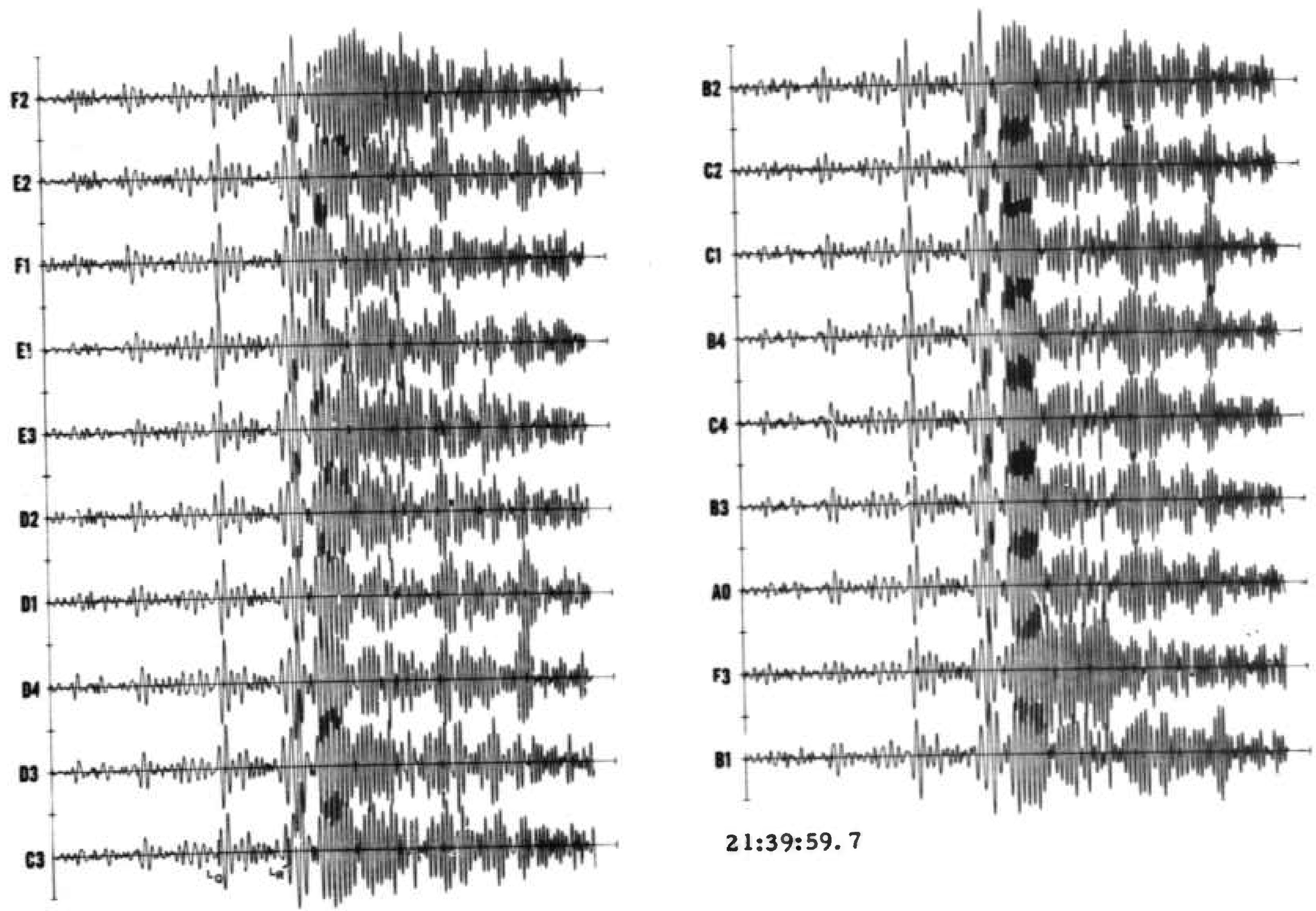
MULTIPLICATIVE SCALE FACTOR = 5

Figure II-11. El Salvador Inline



MULTIPLICATIVE SCALE FACTOR = 5

Figure II-12. El Salvador Transverse



MULTIPLICATIVE SCALE FACTOR = 5

Figure II-13. New Guinea Vertical

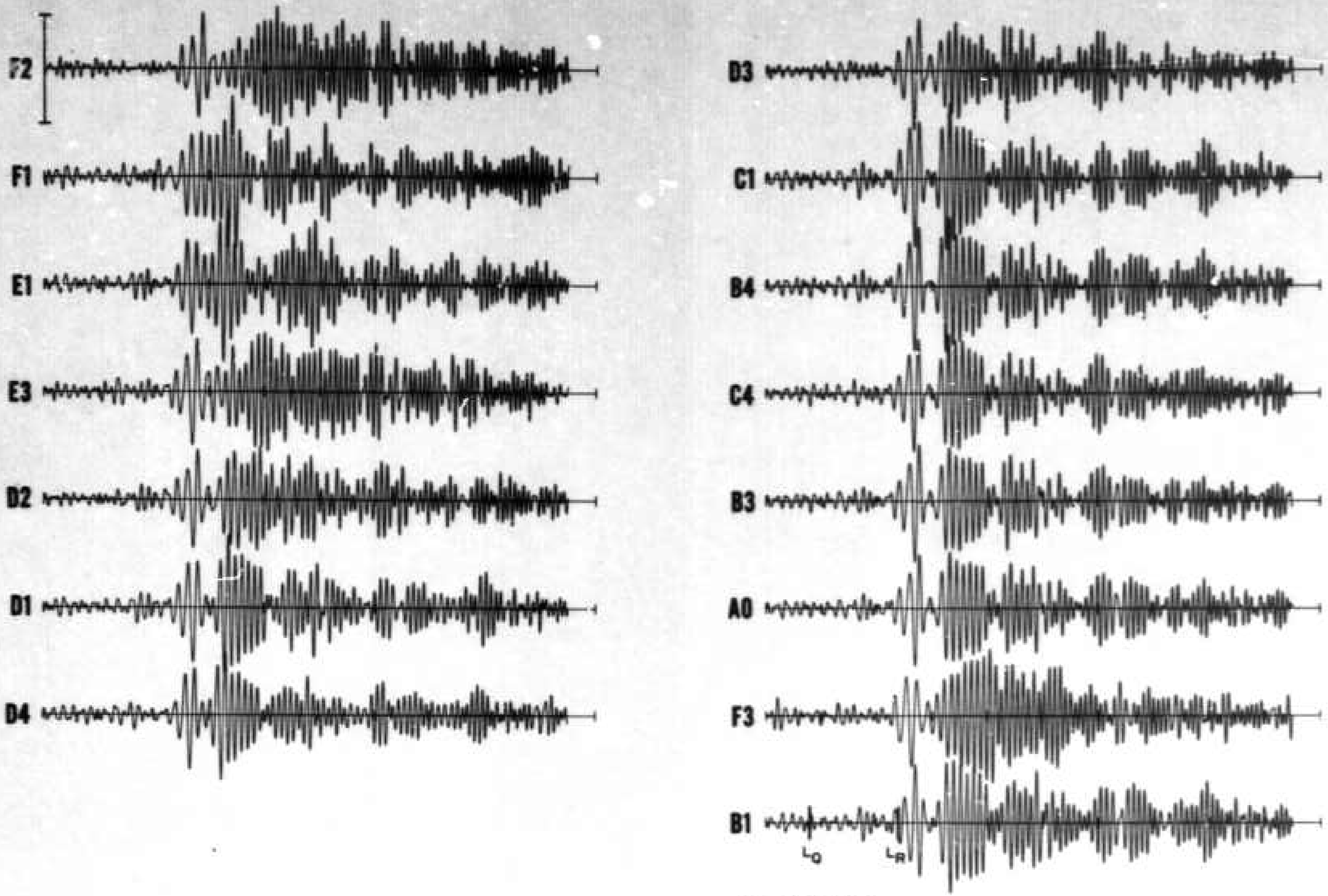


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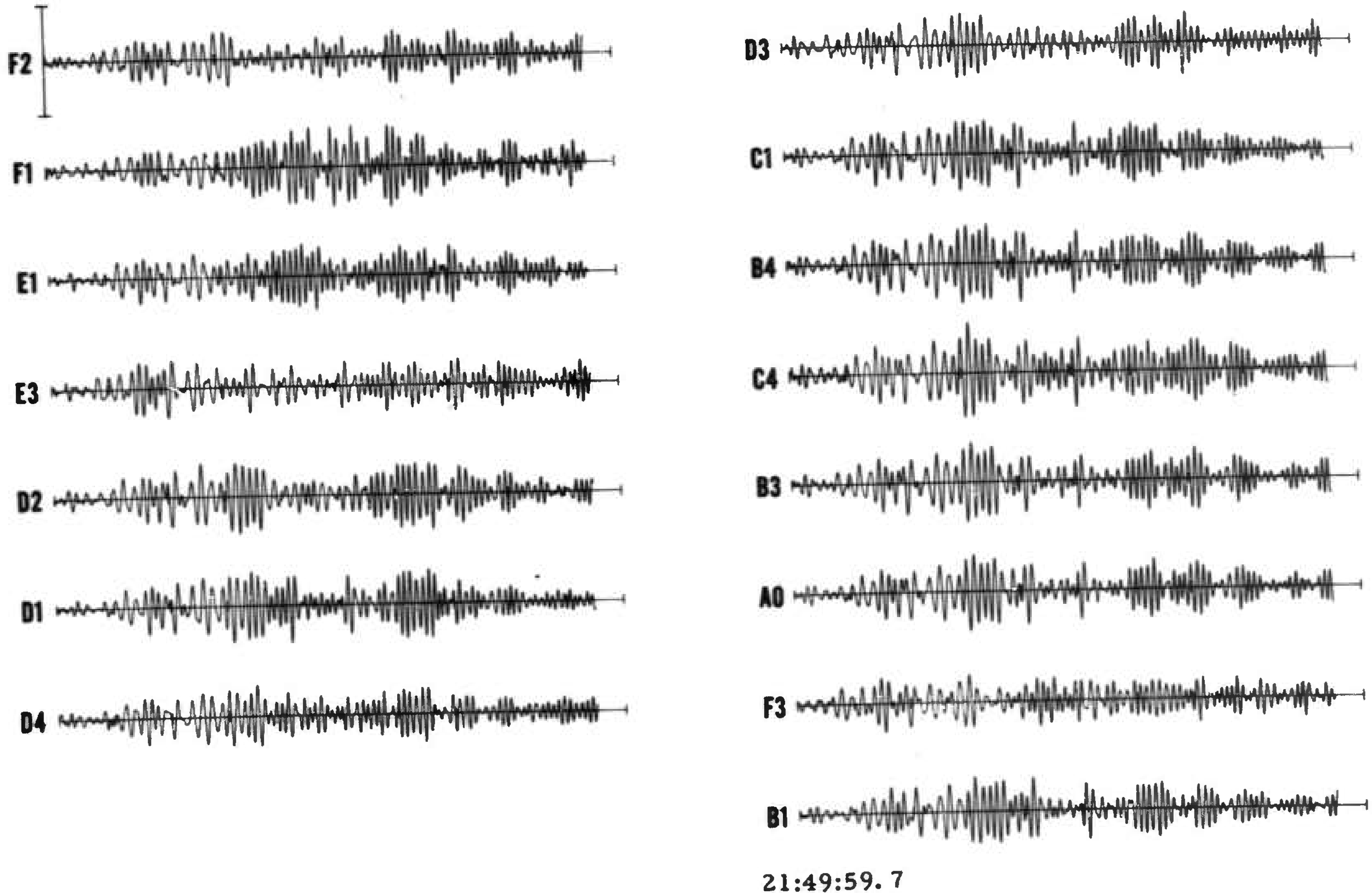
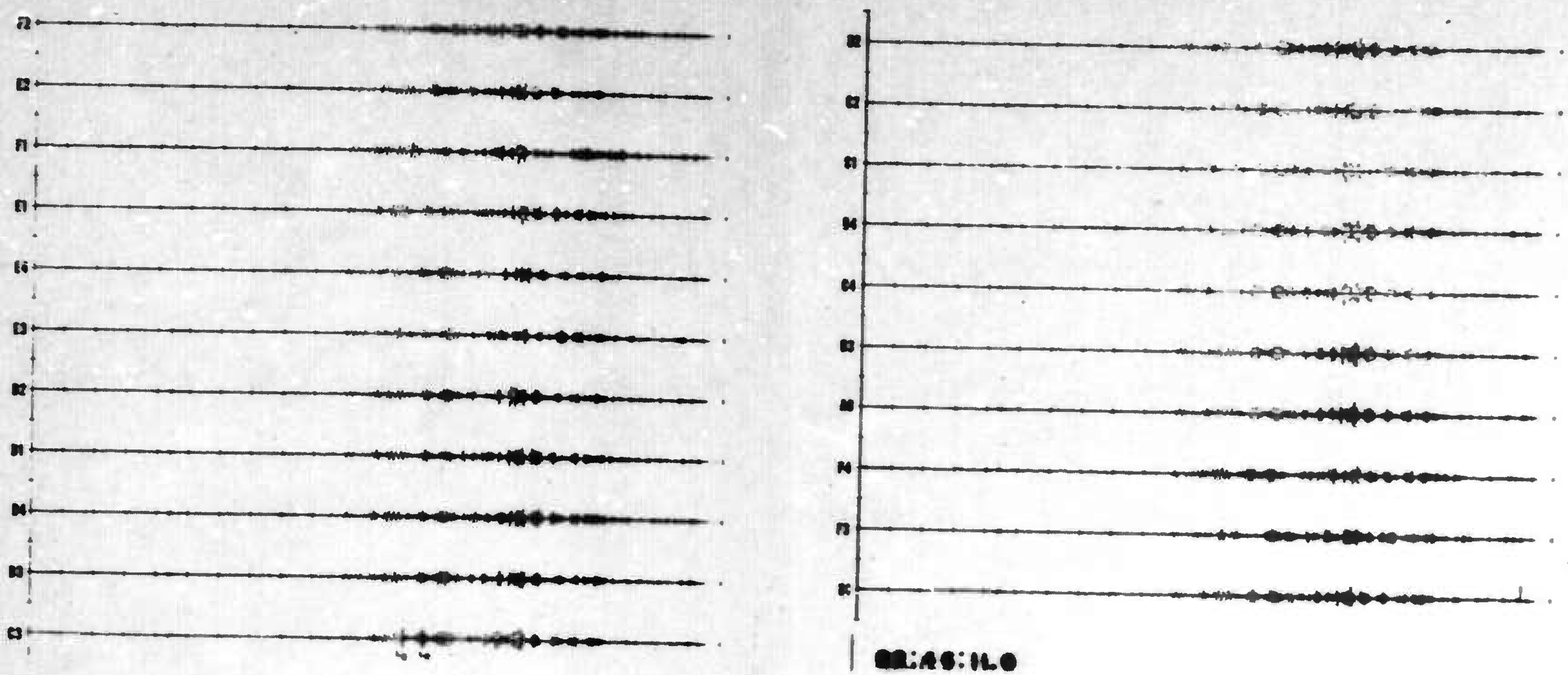
Figure II-14. New Guinea Inline



MULTIPLICATIVE SCALE FACTOR = 4

Figure II-15. New Guinea Transverse



MULTIPLICATIVE SCALE FACTOR = 20

Figure II-16. Virgin Islands Vertical

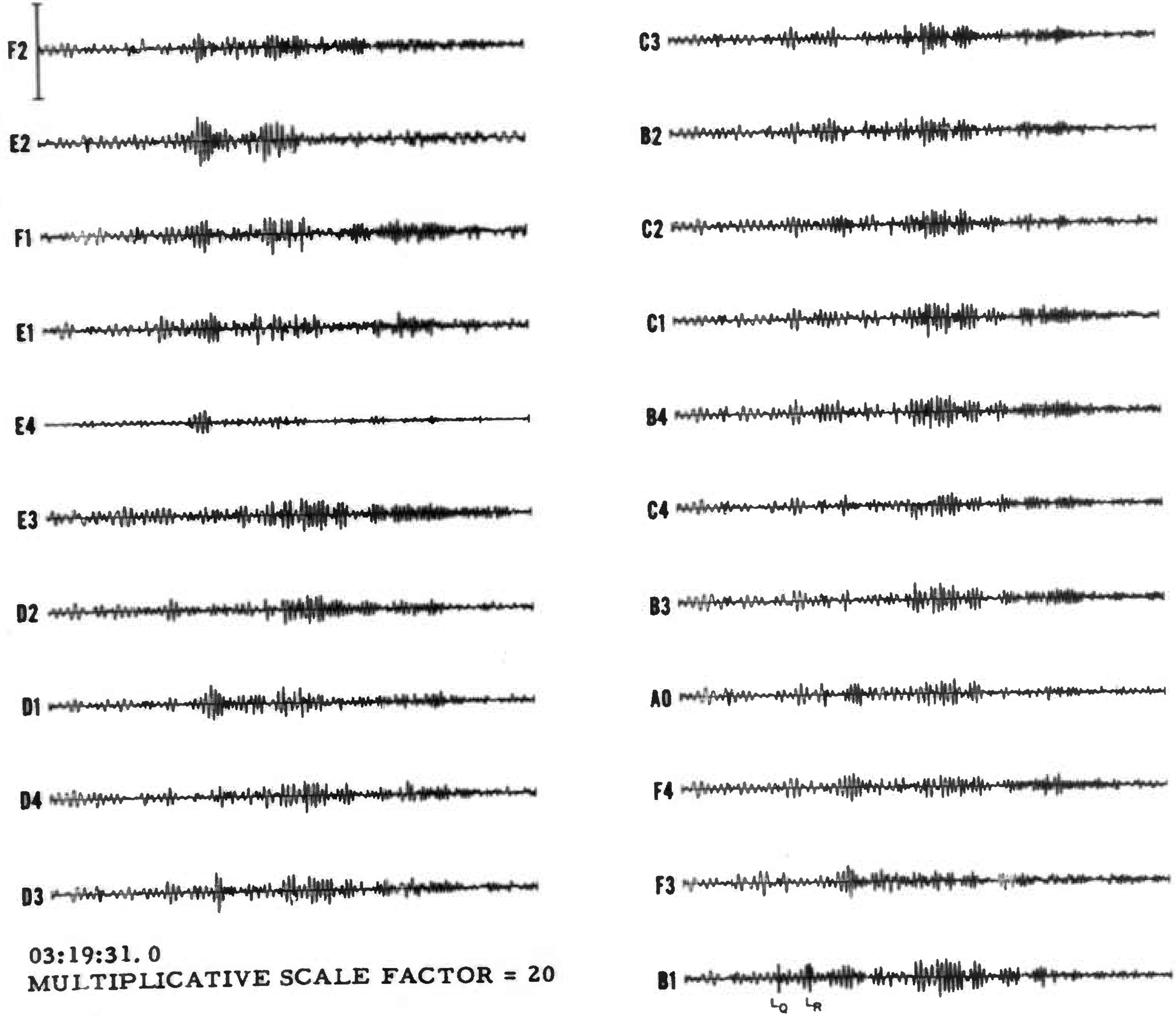


Figure II-17. Virgin Islands Inline

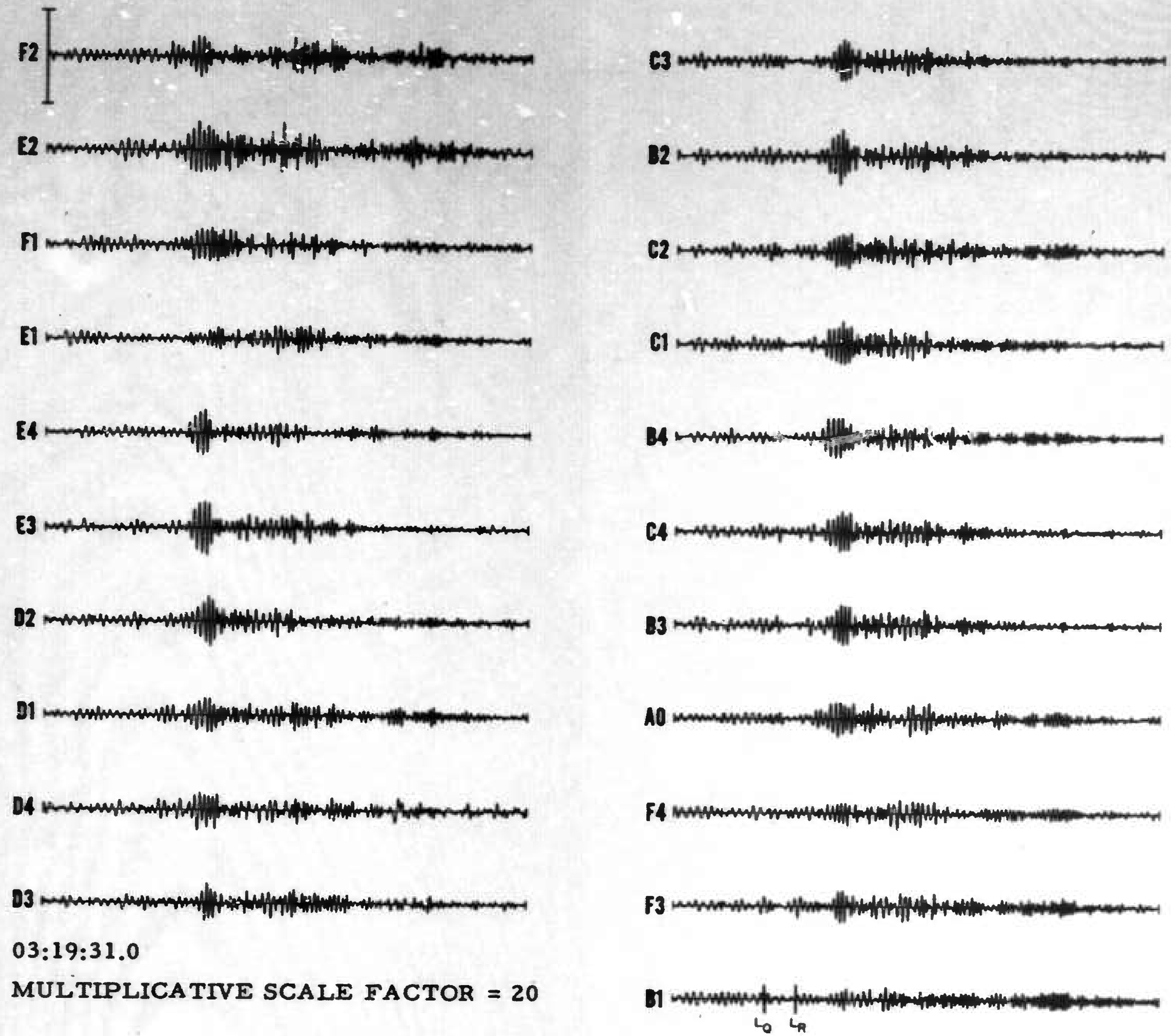
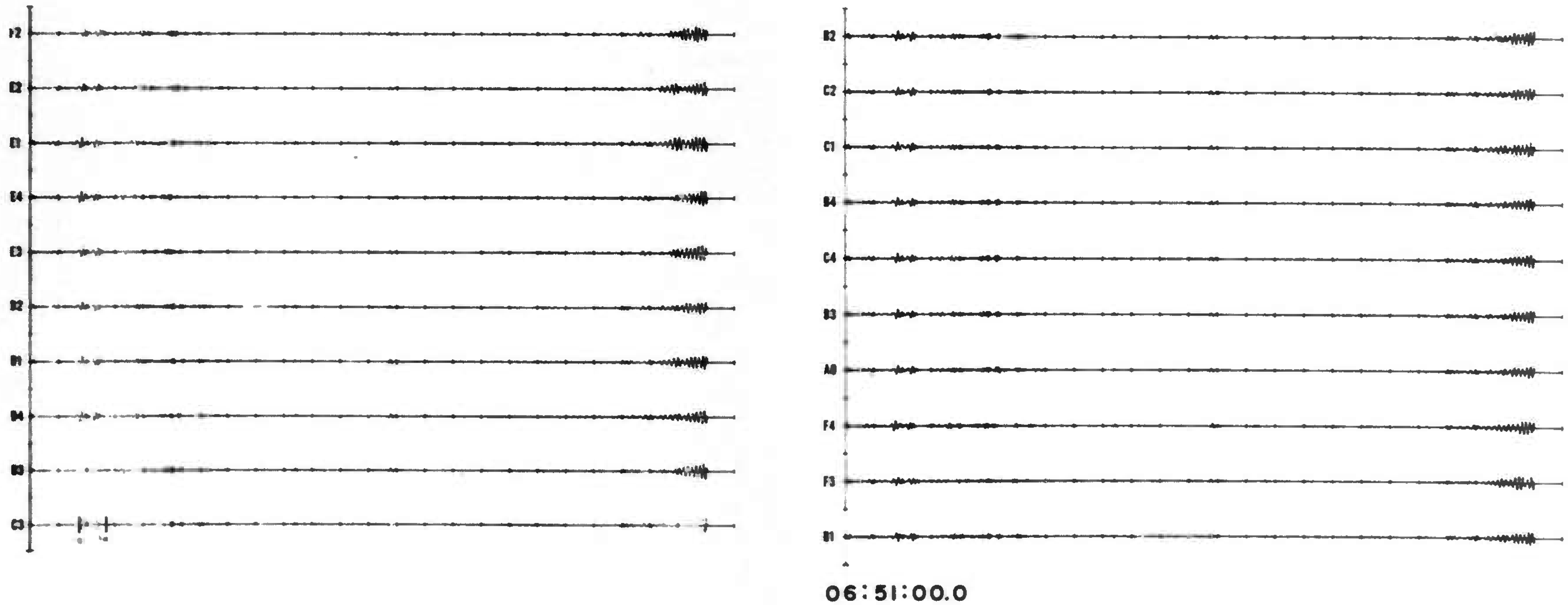
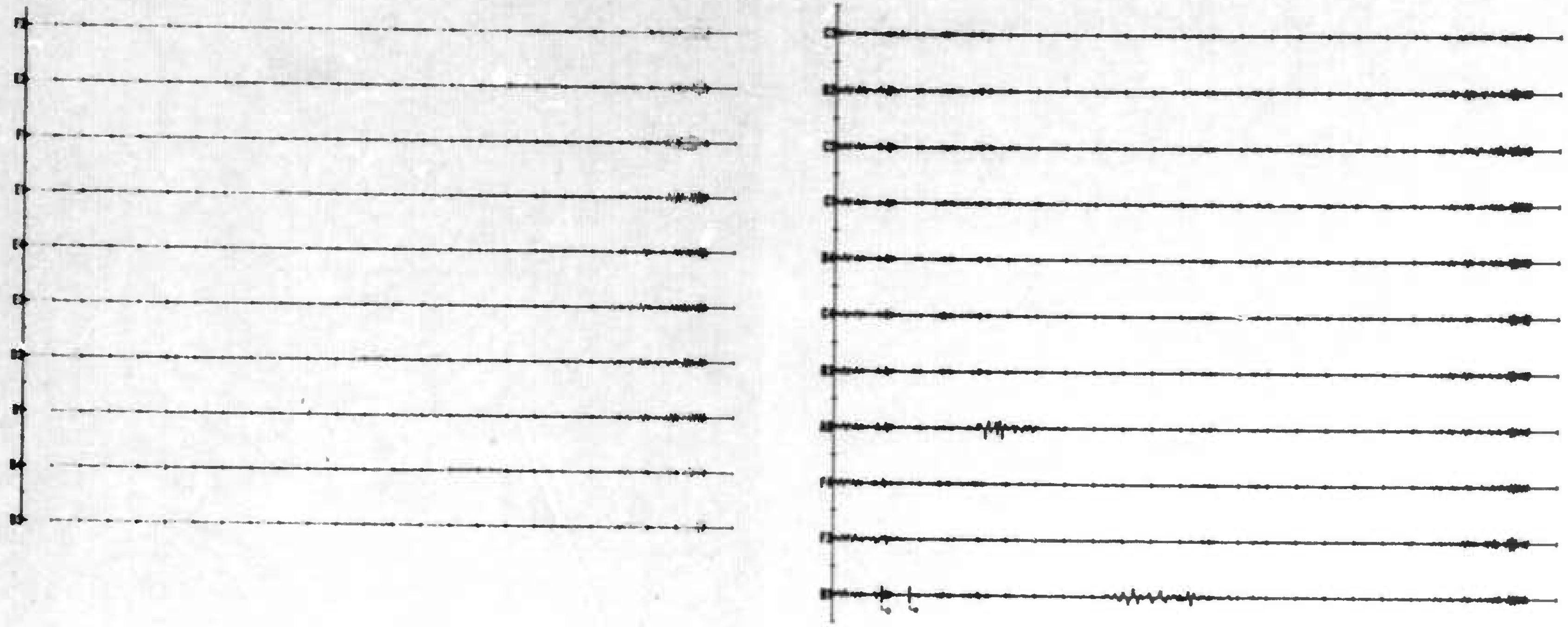


Figure II-18. Virgin Islands Transverse



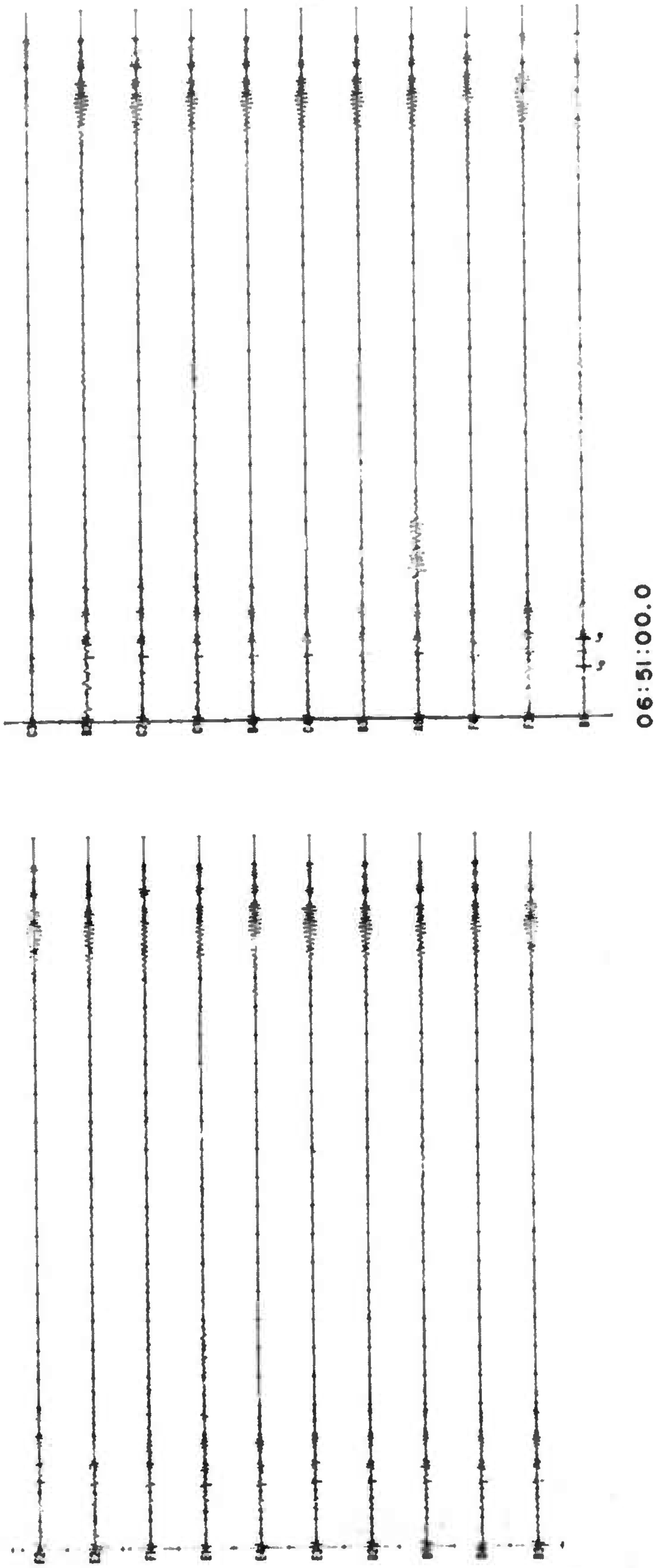
MULTIPLICATIVE SCALE FACTOR = 20

Figure II-19. **Sea of Okhotsk Vertical**



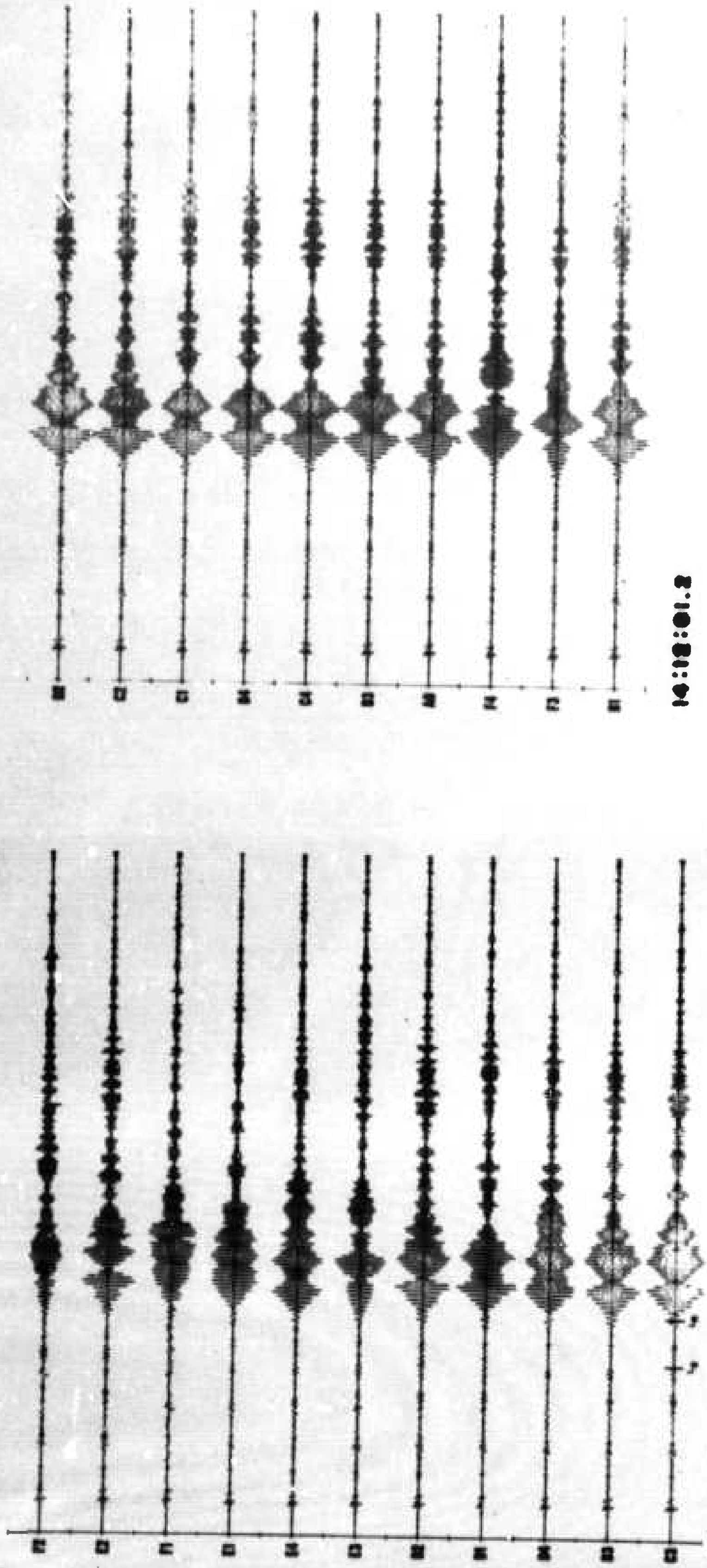
MULTIPLICATIVE SCALE FACTOR = 5

Figure II-20. Sea of Okhotsk Inline



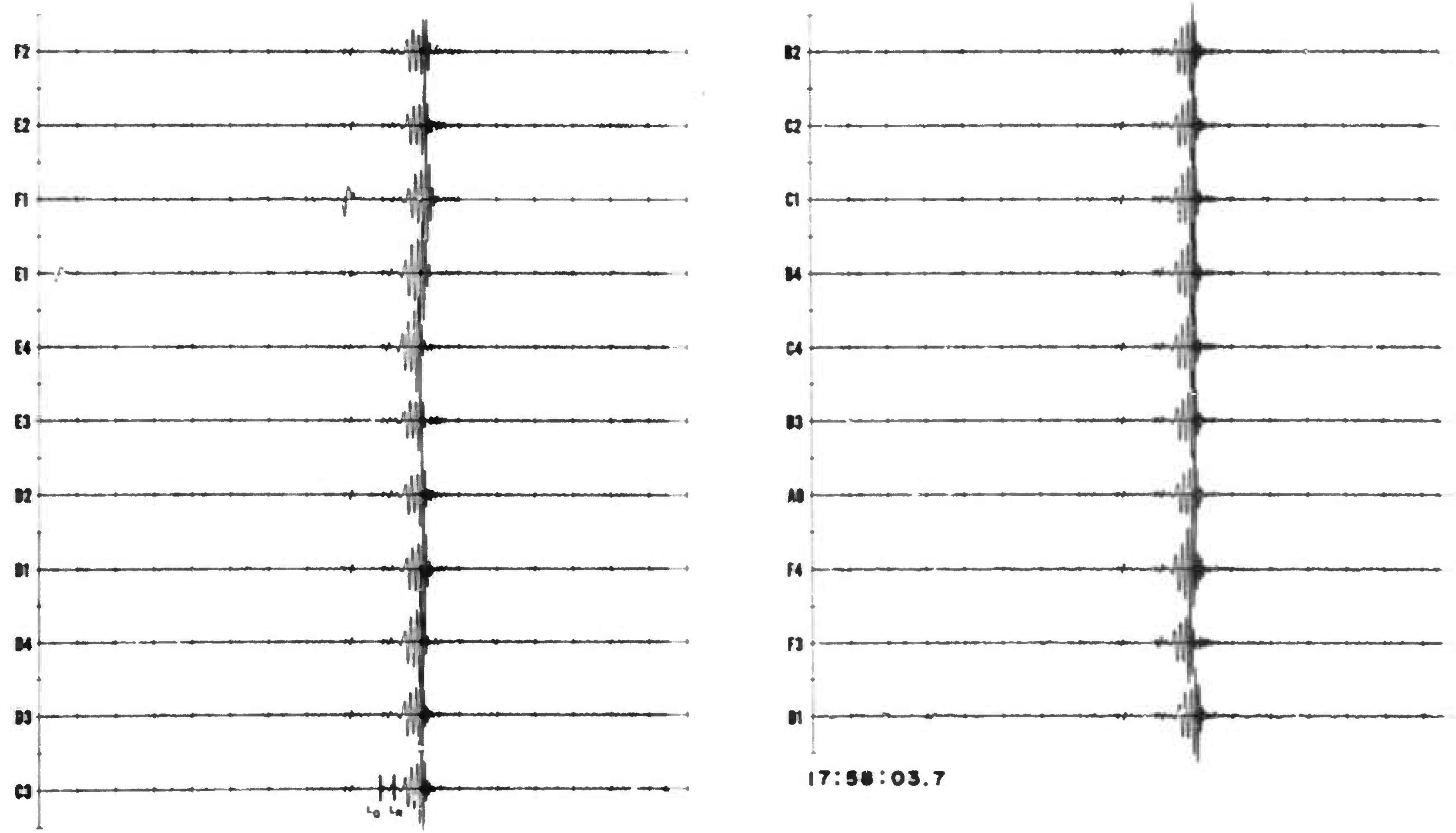
MULTIPLICATIVE SCALE FACTOR = 5

Figure II-21. Sea of Okhotsk Transverse



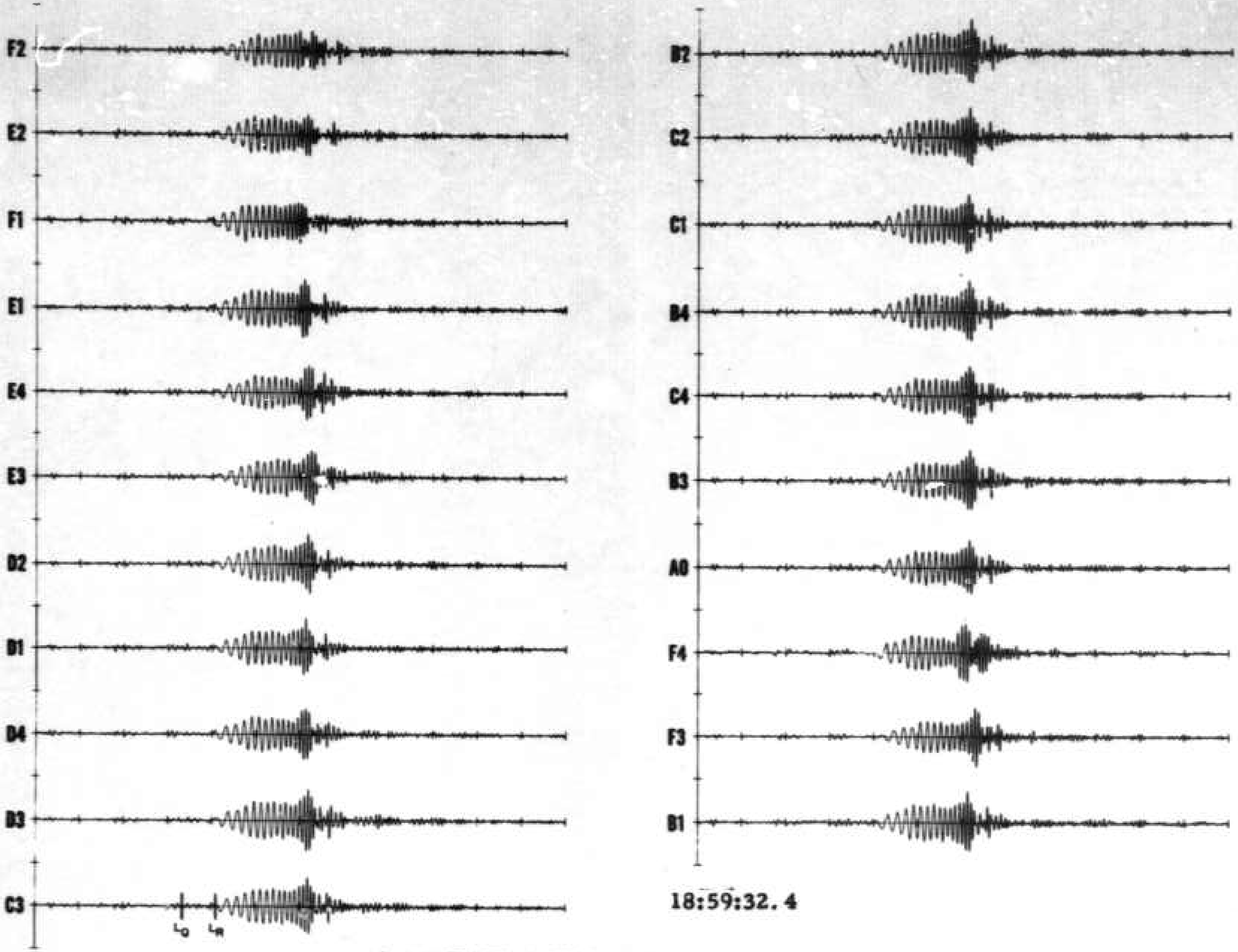
MULTIPLICATIVE SCALE FACTOR = 5

Figure II-22. Solomon Islands Vertical



MULTIPLICATIVE SCALE FAC.OR = 20

Figure II-23. California Vertical



MULTIPLICAT'VE SCALE FACTOR = 20

Figure II-24. Greenland Vertical

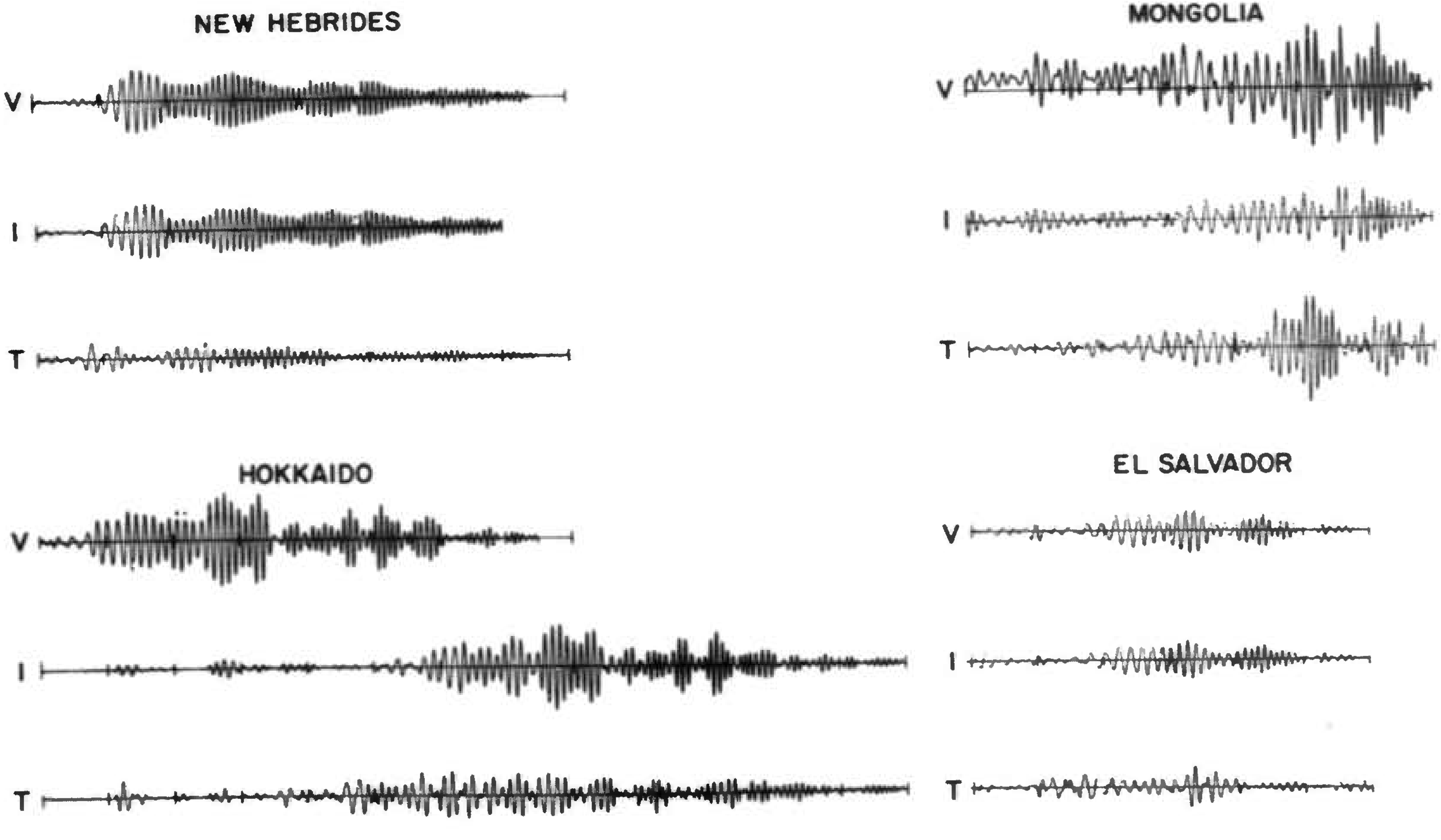


Figure II-25. A0, C- and D-Ring Beamsteers

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14. KEY WORDS	LINK A		LINK B		LINK C	
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Long-Period Summation Processing						
LASA						

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